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METHODOLOGIES
ON CALCULATION OF UNAVOIDABLE TECHNOLOGICAL LOSSES OF ELECTRIC ENERGY IN 0.38-35 KV NETWORKS

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Methodologies on Calculation of Unavoidable Technical Losses of Electric Energy in 0.38-35 kV Networks

1. Major Concepts

Actual (accountable) losses (ΔW_a) of electric energy (hereafter, referred to as electricity)	difference between the electricity entered into the distribution network (or its section) and calculated on the basis of commercial meter readings (W_e) and the electricity delivered from the network (W_o), except for the electricity consumed by customers inside the network.
Technical losses of electricity (ΔW_t)	such amount of active energy used within the network elements during the transmission via the distribution network (hereafter, referred to as a network), which is determined by the mathematical model of network, according to the amount of electricity transmitted during the reportable period.
Allowable metrological losses of electricity (ΔW_{am})	the most probable deviation (positive or negative) of losses measured by tools, from the real value of losses, stipulated by the normative errors of tools
Maximally allowable technological unavoidable losses of electricity (ΔW_{tech})	the most probable technological losses due to transmission technology, which are equal to arithmetic sum of technical losses and metrological
Forecasted losses of electricity (ΔW_f)	normative losses resulted from forecasted regimes of the network operation

2. **General Provisions**

The transmission, conversion and distribution of electricity from energy sources to consumers shall be inevitably accompanied by losses of electricity. The losses shall be determined on the different levels that allows for development of balance sheets of electricity by voltage levels.

- This Methodology contains methods of calculation of consumption of electricity within the network elements during the transmission via 0.38-35 kV network, as well as calculation of the metrological losses accompanying the process of electricity metering.

- The following factors affecting the losses of electricity are taken into consideration:

  a) consumption of electricity during the given period (day, month, quarter, etc)
  b) unbalance in daily consumption of electricity
  c) difference in load profiles by phases
  d) reactive power factor of the total load (by nodes)
  e) locations of separation points of 0.38-35 kV networks
  f) parameters of the electric network elements
  g) probable asymmetry of 0.38-35 kV three-phase network

3. Types and Structure of Calculations of Losses

1. There are three types of calculations of losses depending on the settlement period and the initial data:

    - calculation for the previous (retrospective) period with the data recorded during that period
    - operative calculation (based on the operative current data)
    - prospective calculation (based on the forecasted data to be received in the future)
2. The results of calculation of the most probable unavoidable technological losses within the network should be introduced by the structure containing the following components:

    - load losses on lines, as well as in the transformers
    - idle run losses in the power transformers
    - losses of electricity in reactors
    - losses of electricity in metering devices (meters, metering transformers and other)
    - consumption of electricity in compensating installations (condensing batteries, synchronic and static thyristor converters etc)
    - allowable metrological losses.

2. Method of Calculation of Technical Losses within the Network

The principles of formation of data on regime parameters and network elements and of calculation of stable regime are introduced below.

The following is required for the calculation of technical losses and stable regime of the network operation:

a) determination of passive parameters of the single line equivalent diagram of the network and its elements: lines, transformers.
b) formation of variable active parameters of the network nodes depending on the settlement period and the structure of the initial data
c) selection and implementation of the iterative model of the stable regime of the network operation
d) calculation of the regime parameters of the network elements (flow distribution) and their check-up by allowable limitations
e) calculation of technical losses of the network with the consideration of unbalance factor of the load profile within the settlement period.

1. Determination of the Single Line Network Equivalent Diagram and the Passive Parameters of its Elements

The transmission lines of 0.38-35 kV network are introduced in Picture 1, where r_l – the active resistance of the lines is formulated as follows:

$$r_l = r_{0l}\left[1 + 0.004\left(t_{act} \quad 20\right)\right] \quad \text{(Ohm)}, \qquad (4.1)$$

$$r_{01} = \frac{\ell}{gS} \quad \text{(Ohm)}, \qquad (4.2)$$

where,

r_{0l}- active resistance of the line under +20^{0}C,

ℓ - length of the line (m),

γ - power dencity of the transmission line, equals to 53 for the cooper line and equals to 32 for the alumnum line (m/Ohm·mm^2),

S - cross-section of the line (mm^2),

t_{act} - actual temperature of the line (^{0}C):

x_l reactive resistance of the line is defined as follows:

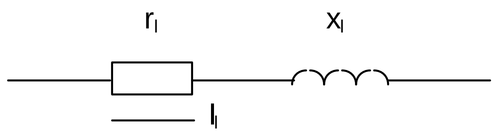
$$x_1 = \quad 0.0157 + 0.144\lg \quad \frac{2D_{\text{between}}}{\text{d}} \quad \ell \quad \text{(Ohm)}, \qquad (4.3)$$

where,

$D_{between}$- distance between transmission lines (cm)

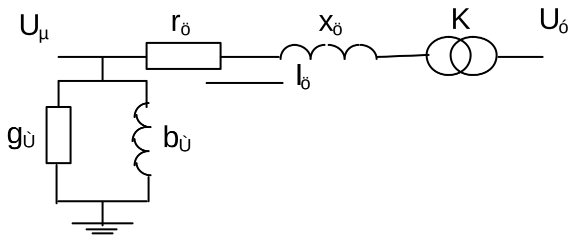
d - diameter of the line (cm):

Values of S, $D_{between}$, d shall be determined according to the types of lines:



Picture 1. Equivalent diagram of the transmission line

The equivalent diagram of the double winding transformer is introduced in Picture 2, where r_w and x_w – the active and reactive resistances, g_c, b_c- the active and reactive capacities simulating electromagnetic phenomena inside the transformer core U_h, U_1- estimated voltages of the high and low voltage transformer windings, respectively, K – transformation ratio of the transformer.



Picture 2. Equivalent diagram of the double winding transformer

$$r_{\mathrm{w}} = \Delta P_{\mathrm{sh}} \frac{U^2_{\mathrm{h\,rated}}}{1000 S^2_{\mathrm{rated}}} \quad \text{(Ohm)}, \tag{4.4}$$

$$x_{\mathrm{w}} = U_{\mathrm{sh}} \frac{U^2_{\mathrm{h\,rated}}}{100 \mathrm{S}_{\mathrm{rated}}} \quad \text{(Ohm)}, \tag{4.5}$$

$$g_{\mathrm{c}} = \frac{\Delta P_{\mathrm{i\,r}}}{1000 U^2_{\mathrm{h\,rated}}} \quad \text{(cm)}, \tag{4.6}$$

$$b_{\mathrm{c}} = i_{\mathrm{i\,r}} \frac{S_{\mathrm{rated}}}{100 U^2_{\mathrm{h\,rated}}} \quad \text{(cm)}, \tag{4.7}$$

where,

S_{rated} rated capacity of the transformer (MWA),

$U_{\mathrm{h\,rated}}$ - rated voltage of the high voltage transformer winding (kV),

ΔP_{sh} - short circuit cpacity (kW),

$\Delta P_{\mathrm{i\,r}}$ - idle capacity (kW),

U_{sh} - short circuit voltage (%),

$i_{\mathrm{i\,r}}$ - idle current (%):

The values of ΔP_{sh}, $\Delta P_{\mathrm{i\,r}}$, U_{sh}, $i_{\mathrm{i\,r}}$ shall be chosen from the information literature or metrological results, whereas the latter is preferable.

2. Formation of Parameters of the Network Node

For the purposes of calculation of the stable regime of the network and of technical losses it is necessary to have the following:

- consumption of the load node active energy within the settlement period (W_i) and the average value of the power factor ($\cos \varphi_l$)

- voltage of the feeding node (U_0)
- active energy of the tree-scheme stem in the settlement period (W_0)
- data path accuracy class of the meter, potential and current transformers.

The average active and reactive capacities of the settlement period are determined for each load and feeding node:

$$P_0 = \frac{W_0}{t} \quad \text{(kW)}, \tag{4.8}$$

$$P_i = \frac{W_i}{t} \quad \text{(kW)}, \tag{4.9}$$

$$Q_i = P_i \mathrm{tg}\varphi_i \quad \text{(kVar):} \tag{4.10}$$

3. Calculation of stabilized regime of the network tree-schemes

The Y-form mathematical model of the network stable regime

$$\overline{Y}\,\overline{U} + \overline{Y}_0\overline{U}_0 = \overline{U}_d^{-1}\overline{S}\,, \tag{4.11}$$

where,

$\overline{Y}$ - matrix of the nodal capacities of multiple of $n \times n$

$\overline{U}$ - column-vector of multiple of n of the nodal complex voltages

$\overline{Y}_0$ - column-vector of total nodal capacities correspondent to the feeding node

$\overline{U}_0$ - complex voltage of the feeding node

$\overline{U}_d^{-1}$ - inverse diagonal matrix of nodal complex voltages,

$\overline{S}$ - column-vector of complex power of the nodal active and reactive capacities,

n - number of nodes (without feeding node):

The nodal voltages, and then branch currents, the active and reactive power flows, power and energy losses within the network elements shall be determined by means of solution of the system of non-linear algebraic equations. The feeding node is considered the base node. If the active power of the feeding node (P_0) is not given, then the feeding node shall be also considered balancing node, according to the active power, otherwise, balancing by active power shall be carried out by means of adjustment of the active power of nodes of load, considering the latter as the proportion ratio.

The stable regime introduced in (4.11) shall be determined by means of the method of Newton, combining it with the parameter method:

$$U^{(\kappa+1)} = U^{(\kappa)} - ß^{-1}F\lambda^{(\kappa)}, \qquad \textbf{(4.12)}$$

where

U - real column vector of multiple of 2n of the true and false components of the nodal voltages of dependent variables of the stable regime,

F - real column vector of multiple of 2n of the irregularities in the active and reactive nodal power,

ß - Jacobs matrix of the multiple of 2nx2n of the (4.10.) system,

λ - a parameter, which value $\lambda \in [0,1]$ is selected given the behavior of the iteration process,

k - step of iteration.

The process of iteration model in (4.12) formula is considered accomplished if the norm of the vector of difference between the nodal voltages in the successive steps of iteration equals to:

$$\left\| U^{(\kappa+1)} - U^{(\kappa)} \right\| < e, \qquad \textbf{(4.13)}$$

where[a] ε - the accuracy level of the solution, introduced in advance.

4. Determination of Regime Parameters of the Network Elements and Technical Losses

Based on the stable regime calculation the nodal (linear) voltages can be determined, which helps to calculate the currents (linear), the active and reactive power flows on lines and transformers.

The active energy losses shall be calculated by the following formula:

$$\Delta W_{.} = \left(K_{ir} I_{lc}\right)^2 r_{lc} t \quad \text{(kWh)}, \qquad (4.14)$$

where, K_{ir} - load unbalance factor,

I_{lc} - average value of linear current (A),

t - duration of the settlement period (h):

The loss of active energy in the transformer winding is formulated as follows:

$$\Delta W_{w} = \left(K_{ir} I_{w}\right)^{2} r_{w} t \quad \text{(kWh)}, \tag{4.15}$$

where,

I_w – the average value of the linear current in the transformer winding.

The loss of the active energy in the transformer core is formulated as follows:

$$\Delta W_{c} = U_{h}^{2} g_{c} t \quad \text{(kWh)}, \tag{4.16}$$

where,

U_h – the estimated voltage is on the high voltage side of the transformer.

5. Load Profile Unbalance Factor

The load profile unbalance factor is determined by the following formula:

$$K_{ir} = K_{1} K_{2} K_{3} \ , \tag{4.17}$$

where K_1 - variability ratio of the three-phase load profile, in case if load is symmetric

K_2 - variability ratio of average values of non-symmetric three-phase load, when the profiles are similar

K_3- variability ratio of load profiles of different phases.

The error in calculation of the load profile unbalance factor (unbalance factor) depends on the level of completeness of the initial data. There are practically three methods, which are classified by the error class. They are:

- accurate calculation method
- approximate calculation method
- estimation method.

1) Accuracy calculation method

The following initial data shall be used:

- the characteristic daily or estimated T time period curves for the load (active and reactive power) and voltage
- n=T/Δt – number of sections

- Δt – discrete value of the time
- P_{Ai}; P_{Bi}; P_{Ci} (shortly P_{mi}, where m =(A,B,C)) -the average values of the active power of consumption of the A, B, C phases, respectively, during the ith period of time, where i =1,2, . . . ,n;
- Q_{Ai}; Q_{Bi}; Q_{Ci} (shortly Q_{mi}) - the average value of the reactive power of consumption of phases A, B, C, during the ith period of time,
- U_{Ai}; U_{Bi}; U_{Ci} – the average values of phase voltages during the ith period of time.

The following values can be determined based on the initial data:

- the average value of current at each phase within ith period of time.

$$I_{mi} = \frac{\sqrt{P_{mi}^2 + Q_{mi}^2}}{U_{mi}}, \quad \text{m = A,B,C, i =1,2, . . . ,n,} \qquad (4.18)$$

- the average value of current at each phase within T period of time.

$$I_{m.ñð} = \frac{1}{n} \sum_{i=1}^{n} I_{mi}, \qquad (4.19)$$

- the average phase voltage within ith period of time.

$$\mathrm{U_i} = \frac{1}{3}\left(\mathrm{U_{Ai}} + \mathrm{U_{Bi}} + \mathrm{U_{Ci}}\right), \qquad (4.20)$$

- the average phase voltage within T period of time.

$$U_{av} = \frac{1}{n} \sum_{i=1}^{n} U_i, \qquad (4.21)$$

- the average values of the active and reactive components of current in the neutral transmission line, within ith period of time.

$$\mathrm{I_{aNi}} = \mathrm{I_{Ai}} \cos \varphi_{\mathrm{Ai}} + \mathrm{I_{Bi}} \cos\left(120^0 + \varphi_{\mathrm{Bi}}\right) + \mathrm{I_{Ci}} \cos\left(120^0 - \varphi_{\mathrm{Ci}}\right), \qquad (4.22)$$

$$I_{\mathrm{ðNi}} = I_{Ai} \sin j_{Ai} + I_{Bi} \sin\left(120^0 + j_{Bi}\right) + I_{Ci} \sin\left(120^0 \quad j_{Ci}\right), \qquad (4.23)$$

where

$$\varphi_{\mathrm{mi}} = \mathrm{arctg}\left(\mathrm{Q_{mi}} / \mathrm{P_{mi}}\right), \qquad (4.24)$$

- the total value of current at the neutral transmission line within ith period of time:

$$I_{Ni} = \sqrt{I_{aNi}^2 + I_{\text{ðNi}}^2}\,, \qquad (4.25)$$

- the average value of the total current within the T time period

$$I_{N\text{av}} = \frac{1}{n}\sum_{i=1}^{n} I_{Ni}\,, \qquad (4.26)$$

- the square value of the average capacity consumed during the T time period:

$$S_{\text{av}}^2 = \left\langle \sum_{i=1}^{n} P_i \right\rangle^2 + \left\langle \sum_{i=1}^{n} Q_i \right\rangle^2, \qquad (4.27)$$

where,

$$\mathrm{P_i} = \mathrm{P_{Ai}} + \mathrm{P_{Bi}} + \mathrm{P_{Ci}}\,, \quad \mathrm{Q_i} = \mathrm{Q_{Ai}} + \mathrm{Q_{Bi}} + \mathrm{Q_{Ci}}: \qquad (4.28)$$

The unbalance factor is determined by the calculated values:

$$K_{\text{unb}} = \frac{3nU_{\text{av}}^2}{S_{\text{av}}^2}\sum_{i=1}^{n}\left(I_{Ai}^2 + I_{Bi}^2 + I_{Ci}^2 + FI_{Ni}^2\right), \qquad (4.29)$$

$$F = R_N / R_{\text{Ph}}\,, \qquad (4.30)$$

where

R_N, R_{Ph} - resistances of the neutral and phase transmission lines

K_{unb} – factor, which is calculated for each branch of the network scheme and is included into the (4.14) and (4.15) formulas.

The degree of impact of several factors on the level of losses can be clarified, using K_1, K_2, K_3.

$$K_1 = \frac{nU_{\text{av}}^2}{S_{\text{av}}^2}\sum_{i=1}^{n}\frac{P_i^2 + Q_i^2}{U_i^2}\,, \qquad (4.31)$$

$$K_2 = \frac{3n^2U_{\text{av}}^2}{S_{\text{av}}^2}\left(I_{A\text{av}}^2 + I_{B\text{av}}^2 + I_{C\text{av}}^2 + FI_{N\text{av}}^2\right), \qquad (4.32)$$

$$K_3 = K_{\text{unb}} / \text{Ê}_1 K_2\,, \qquad (4.33)$$

The measures on decreasing of losses in the network are developed based on the analysis of K_1, K_2 ,K_3 factors

In the formulas (4.29) and (4.32) for three-wire networks the I_{Ni} =0

The method error of the given formulas is conditioned by the value of time only - Δt. To ensure the highest accuracy of calculations the value of Δt is accepted as $\Delta t \leq 10$ minutes.

The contemporary metering, registering electronic devices allow to perform the necessary measurings in the network for any value of Δt, measure the average values of metered data, have the best opportunity to transfer the data to the computer.

2) Approximate calculation method

The following initial data shall be used:

- load curves of ach load (current) of three-wire and neutral wires, received by means of periodic measurements (manual or automatic) during the characteristic daily or estimated T time period.
- I_{Ai} ; I_{Bi} ; I_{Ci} ; I_{Ni} - the average values of currents of the neutral wire and the A, B, C phases in the i^{th} period of time, where I=1,2,….,n.

Based on the given data, the unbalance factor equals to:

$$K'_{unb} = \frac{3n}{D} \sum_{i=1}^{n} \left(I_{Ai}^2 + I_{Bi}^2 + I_{Ci}^2 + F I_{Ni}^2 \right), \qquad (4.34)$$

accepting that $U_{Ai} = U_{Bi} = U_{Ci} = U$ and $\cos\varphi_{Ai} = \cos\varphi_{Bi} = \cos\varphi_{Ci} = \cos\varphi$,

$$D = \sum_{i=1}^{n} \left(I_{Ai} + I_{Bi} + I_{Ci} \right)^2, \qquad (4.35)$$

The application of the K'_{unb} factor coincides with the application of the K_{unb} factor (see 4.17).

The following values are determined based on the initial data:

$$K_1' = \frac{n}{D} \sum_{i=1}^{n} \left(I_{Ai} + I_{Bi} + I_{Ci} \right)^2, \qquad (4.36)$$

$$K_2^{'} = \frac{3n^2}{D}\left(I^2_{A\tilde{n}\eth} + I^2_{B\tilde{n}\eth} + I^2_{C\tilde{n}\eth} + FI^2_{N\tilde{n}\eth}\right), \tag{4.37}$$

$$K_3^{'} = K_{unb}^{'} \Big/ K_1^{'} K_2^{'} : \tag{4.38}$$

The values of I_{mav} and I_{Nav} currents shall be determined by the formulas (4.19) and (4.26), respectively.

I_{Ni} =0 is accepted at the three-wire network.

In this case the method error in the calculation of losses is conditioned by the following approximations:

- the selected value of Δt. It can be neglected, if we consider that $\Delta t \leq 10$ minutes and carry out measurements for each Δt, where I=1,2,…,n.
- the line voltages U_{mi} and power factors are accepted unchangeable.

3) Estimation Method

The following initial data shall be used:

W – the active energy of the three-phase current transmitted during the T time period via the given element of the network.

I_{max}, I_{min} – the maximum and minimum values of current during the T time period

$U_{av}, \cos j_{av}$ - the average weighted values of the voltage and power factors, respectively, within the T time period (as a rule, these values shall be determined by the experimental estimate)

The variability ratio of load curve shall be determined using this method:

$$K_1'' = \frac{(1 + 2p + d)p - d}{3p^2}, \tag{4.39}$$

where,

$$p = \frac{I_{av}}{I_{max}}, \quad d = \frac{I_{min}}{I_{max}}, \tag{4.40}$$

$$I_{av} = \frac{W}{\sqrt{3}TU_{av} \cos j_{av}} : \tag{4.41}$$

The K_1'' factor is applied instead of the K_{unb} factor.

The probability of calculation errors is various and depends on the form of the load curve, which in certain cases can contain major values.

5. Calculation of Technical Losses of Electricity

1. The technical losses of electricity within the network principle elements (DW_i) (network elements: all types of lines, transformers, reactors and capacitor bank)

The amount of electricity, which is unavoidably transformed into the other types of energy (thermal, laser, etc) during transmission (distribution) of electricity through the electric network, is called the technical loss of electricity. The losses of electricity within the network elements shall be determined by values of the active power losses in those elements and be computed by means of summation of losses of the active power for each hour of the settlement period. The loss of electricity in the entire network shall be the sum of electricity losses in each network element.

2. Other Components of Technical Losses

The losses within the metering facilityes of the electric network, such as current and potential transformers, electric meters, secondary metering circuits, are also classified as technical losses.

1) The energy losses in the potential and current transformers, including losses within their secondary circuits (meters, connection lines), can be estimated based on the values of average losses within them, in case of three phases(see the Table).

Voltage, kV	6	10	35	110	220
Part of the current transformer, kWh/year	60	60	100	300	300
Part of the potential transformer, kWh/year					

2) The technical losses of energy in capacitor bank shall be formulated by one of the following formulas:

$$\Delta W_{cb} = \Delta p_0 Q_{cb} T_{cb}, \quad \text{or} \quad \Delta W_{cb} = \Delta p_0 V \ , \ \text{(kWh)} \qquad (5.1)$$

where Δp_0 - specific losses of capacity in the capacitor (kW/kVar). For capacitors with the voltage higher than 1000 V the value of $\Delta p_0 = 0.002$ kW/kVar is acceptable

Q_{cb}, T_{cb} – the installed capacity of the capacitor bank (kVar) and the and number of operational hours (hours)

V – the reactive energy of the capacitors bank within the settlement period (kVarh)

3) The power and energy losses in the reactors of the network shall be calculated as follows:

- the active power losses in three phases:

$$\Delta P_{é} = 3 I_{*}^{2} \Delta P_{зÝí.ý} \text{ (kW)} \qquad (5.2)$$

where $\Delta P_{nom.Ph}$ - the active power loss in one phase of the reactor in case of nominal load (kW);

$I_{*} = I / I_{nom}$ - ratio of the actual current of the reactor to the nominal current

- the reactive power losses in three phases

$$\Delta Q_{r} = 3 I_{*}^{2} \Delta Q_{nom.Ph} \text{ (kVar)} \qquad (5.3)$$

$\Delta Q_{nom.Ph}$ – the reactive power loss in one phase of the reactor

- the active and reactive power losses in three phases

$$\Delta W_{r} = \Delta P_{r} T_{r} K_{unb}, \text{ (kWh)} \qquad \Delta V = \Delta Q_{r} T_{r} K_{unb} \text{ (kVarh)}, \qquad (5.4)$$

where T_r – the number of hours when the reactor is connected (hour).

6. Calculation of Metrological Losses

The maximum allowed value of the metrological losses is formulated as follows:

$$\Delta W_{m.a} = \sqrt{ \overset{n}{\underset{i=1}{?}} \left(\frac{W_{\cdot i}}{W_{i}} d_{\cdot i} \right)^{2} + \overset{m}{\underset{j=1}{?}} \left(\frac{W_{\mu j}}{W_{i}} d_{\mu j} \right)^{2} } \ \%, \qquad (6.1)$$

where,

n – number of input connections

W_{qi} – the energy received by the qi input connection

m – number of output connections

W_{bj} – the energy transmitted by the bj output connection

δ_{qi} – the error of the metering facility of the qi input connection, %

δ_{bj} - the error of the metering facility of the bj input connection,%

$$\delta = \pm 1.1\sqrt{\delta_I^2 + \delta_U^2 + \delta_O^2 + \delta_\theta^2} + \delta_L \qquad (6.2.)$$

where,

δ_I and δ_U – the allowed marginal errors (%) of the current and potential transformers, respectively (CT, PT)

δ_L – the allowed marginal loss of voltage in transmission lines connecting the potential transformer and the electric meter (%).

δ_0 – the allowed marginal value of the basic error of the meter, %

δ_θ - the angle error of the metering facility conditioned by the angle errors of the current and potential transformers, %

The allowed value of δ_L (systematic error) is δ_L=0.5δ_U.

$$d_q = 0.029\sqrt{q_I^2 + q_U^2}\, tgj \ , \qquad (6.3)$$

where, θ_I and θ_U – the values of the angle allowed marginal error of the current and potential transformers, respectively.

tgφ- the reactive power factor of the controlled connection.

The value of $\Delta W_{m.a}$ in (6.1) formula is taken for positive and negative values of δ (δ>0 and δ<0). Consequently, the allowed maximum and minimum values of metrological losses shall be determined by (6.1) formula.

7. Calculation of the Maximum Allowed Technological Unavoidable Losses

According to the definition, the maximum allowed technological unavoidable losses shall be formulated as follows:

$$\Delta W_{\text{tech}} = \Delta W_{\text{t}} + \Delta W_{\text{m.a}}, \qquad (7.1)$$

where, ΔW_t - the technical losses of energy in the electric network

$\Delta W_{m.a}$ - the maximum allowed metrological losses conditioned by the metering facility error

The energy actual losses shall be determined by the formula:

$$\Delta W_a = W_m - W_n \tag{7.2}$$

The order of making calculations of the allowed unavoidable technological losses of energy is as follows:

- the actual losses of energy for the settlement period (ΔW_a)are determined by formula (7.2);
- the maximum allowed value of metrological losses ($\Delta W_{m.\ a}$) is determined by formula (6.1);
- the maximum allowed values of unavoidable technological losses are determined by formula (7.1);
- the maximum allowed values of unavoidable technological losses are compared with the actual losses.

The actual losses should not exceed the maximum allowed value of unavoidable technological losses: $\Delta W_a \leq \Delta W_{tech}$: In this case the actual value of losses is considered the allowed value of losses. If $\Delta W_a > \Delta W_{tech}$, the maximum allowed technological unavoidable losses shall be considered the allowed losses and the unbalance (excessive losses) shall be determined:

$$\Delta W_{unb} = \Delta W_a - \Delta W_{tech}$$

8. Requirements to the Software on Calculation of Losses within 0.38-35 kV Networks

1. The following requirements shall be introduced to the software package on calculation of losses within the above-mentioned networks and on development of correspondent measures on decrease of losses:
   a) creation of a databank on 0.38-35 kV networks;
   b) calculation of the average value of current in 0.38-35 kV networks by incomplete initial data;
   c) calculation of the maximum value of current in 0.38-35 kV networks by incomplete initial data;
   d) determination of the optimal scheme of 6(10) kV networks and estimation;
   e) calculation of losses of energy in 0.38-35 kV networks.

2. The data bank creation software package shall provide the following functions:

1) recording of initial data on single-line diagram of 0.38-35 kV networks:

- development of lists of all topological nodes of the network by all feeding transmission poles of the substations, distribution points, transformer and plant substations, network separation points;
- development of data on contents of each node (power transformer, separator, safety lock, current transformer, etc.);
- development of data on branches of the topological tree, registration of their operational status (under operation, in reserve, with disconnected end , etc.)
- development of data on contents of each branch (transmission line, its length, type of material, parallel lines, breaker, safety lock, etc.).

2) databank; refinement, amending;

3) disclosure of errors in the databank, including:

- contour in the network
- nods without feeding (“frozen”)
- repetition of records
- inconsistence in the node-related and branch-related records

4) obtaining of the topological tree of 0.38-35 kV network, in particular:

- storage of the tree number and the quantity of branches,
- sequential recording of branches of the whole tree starting from the head branch of the feeding direction, by the occupied topological position of the branch,
- obtaining of the list of separated branches, where the disconnected end of the branch is specified and the numbers of trees connected via that branch.

5) Construction of the topology of the electric feeding direction in 0.38-35 kV networks, sequential registration of its branches by the topological position and registration of the head branch of the reviewed tree.

6) creation of list of nodes of each tree in the network, registration of all primary circuits connected in nodes.

7) development of the list of branches of each tree of the network, registration of elements of all branch circuits.

8) development of data on transmission cable lines

- records on the branch failure (branch name, date and hour of the branch failure)

- records on the location of the disclosed failure of the given branch;
- records on rehabilitation of operability of the given branch (day, month, hour)
- records on the given branch testing (day, month, hour)
- records on implementation of control over the rehabilitated branch, as well as on grounding of the ends of that branch

9) Records on the type of the equipment (electric installation) and location

- to create data directories on all types of equipment and electric installations;
- to record the type number of the equipment in the correspondent line of the data bank, by the occupied location
- to record the type of the equipment in the given part of the network.

10) The “Databank” software enables the following processes:

- to include in the information software the data on separate network organizations;
- to combine the data on separate network organizations into one joint databank;
- to detach the data on separate parts of the network from the network organizations databank, in other words, to create a databank on each separate part of the network.

3. Approximate determination of missing data for the calculation of average values of the nodal currents of 0.38-35 kV network, by the structure of the given feeding direction and the topological structure, as well as by the meter readings and the known data on the power factors.

   The average values of currents of all branches at the given direction shall be calculated based on the determined average values of the nodal currents.

4. Determination of the maximum values of currents of the elements at the given direction, according to the direction structure, topology, characteristic days, hours and the results of measurements of the maximum currents at nodes.
5. Determination of the optimal locations of the separation points of 6-10 kV network, calculation of the reduced value of losses, which is envisaged after the optimization of separation points.

The software package should function with the consideration of all possible technical and regime limitations of the task, including the allowed scale of fluctuations of current and voltage.

6. Calculation of energy losses in 0.38 kV network:

   The initial data is as follows:

   - the single-line diagram of the network fed from each transmission line (feeder) outgoing from 0.4 kV poles of 6-10/0.4 kV transformer, and parameters of each element.
   - the amount of electricity transmitted via the mentioned line (feeder) within the reviewed settlement period.

To carryout calculation of energy losses in the reviewed network (networks).

In case of availability of several networks fed from the given transformer, the total value (sum) of losses in all networks should be calculated.

7. Calculation of energy losses in 0.38 kV network fed from the distribution transformers of the 6-10 kV network tree.

   The initial data is as follows:

   - the single-line diagrams of all 6-10 /0.4 kV transformers at the mentioned direction and 0.38 kV networks fed from transmission lines (feeders) outgoing from those transformers, and parameters of their element.
   - the amounts of electricity transmitted via the mentioned lines (feeders) within the reviewed settlement period.

   To carry out calculation of energy losses in 0.38 kV network.

8. Generalized calculation of energy losses in 0.38-35 kV networks:

   The initial data is as follows:

   - all parameters of branches of 0.38-35 kV networks, which are stored in the databank;
   - the amounts of electric energy transmitted within the settlement period via the head elements of the network and the low side of the distribution potential transformers of 6-10/0.4 kV.

   The following data should be calculated by means of the software package and printed out:

   - the losses of energy in all power transformers of the network (idle run losses and under load);
   - the losses of energy in all transmission lines of the network;
   - the allowed metrological losses of energy ;
   - the generalized data on energy losses in the reviewed network within the settlement period, by discrete rings;
   - the maximum unbalance (excessive losses), the list of discrete rings having losses;

- the list of sections (branches) exceeding the value of the maximum allowed current;
- the list of nodes deviated from the allowed voltage;
- the list of overloaded power transformers;
- the list of discrete rings having the maximum allowed technological unavoidable losses.